Coupled Simulation of a Room Air-conditioner with CFD Models for Indoor Environment

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Abstract

The assessment of closed-loop performance of HVAC systems often requires an integrated approach that couples the dynamic models of HAVC system with building energy simulation programs. Most of these building simulation programs assume that indoor air is well mixed in order to simplify the computation. However, this prevailing assumption fails to simulate the distribution of temperature, pressure, concentration in buildings with large space and high heat gain. As a result, these programs cannot accurately predict building energy consumption and the closed-loop performance of HVAC system. In addition, they cannot satisfy advanced design requirements, such as personal cooling/heating and optimal sensor placement, due to lack of local thermal comfort information.

In contrast with the well-mixed assumption, computational fluid dynamics (CFD) divides fluid domain into a large number of small volumes such that a detailed prediction of airflow and temperature distributions, thermal comfort and indoor air quality can be obtained. Coupling building energy simulation programs with CFD can be effective to overcome the deficiencies of stand-alone programs and achieve better results. Consequently, building simulations can provide dynamic boundary conditions to CFD, whereas CFD simulates the airflow dynamics based on these boundary conditions and then can send the average airflow and temperature information back to building simulations such that the closed-loop performance of HVAC system can be evaluated.

Comprehensive review of the literature indicates that coupled simulation of building energy systems (BES) and CFD often focuses on the integration of air handlers with indoor environment, and does not incorporate vapor compression systems into the analysis, yielding inaccurate prediction of building energy consumption. Meanwhile, the reported coupled simulations are all based on the commercial CFD programs rather than open-source code. To bridge the research gap, this paper attempts to couple the dynamic models of a room air-conditioner with detailed CFD model for indoor environment to explore the pull-down performance of the system with different vane angles and airflow modes. The dynamic models of the air-conditioner are constructed in Modelica, whereas the indoor environment is simulated in OpenFOAM. The use of coupled simulation facilitates more accurate exploration of system dynamics than using the well-mixed air model due to the inherent non-uniform air flow and temperature distributions in buildings.

Keywords: Modelica, OpenFOAM, co-simulation, building energy simulation, vapor compression system

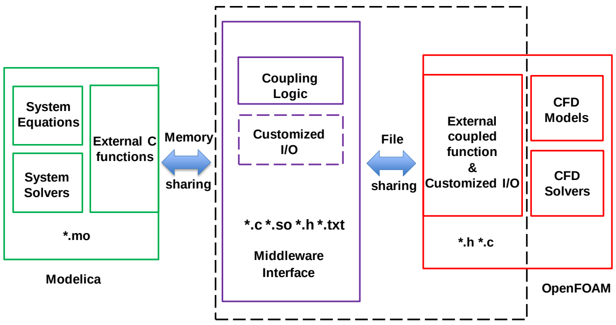

Figure 1. Coupling between Modelica and OpenFOAM.